CHEMISTRY LETTERS, pp. 893-896, 1991.

Novel Reduction of Carboxylic Acids with Samarium Diiodide

Yasuko KAMOCHI and Tadahiro KUDO*
Daiichi College of Pharmaceutical Sciences, 22-1 Tamagawa-cho,
Minami-ku, Fukuoka 815

Carboxylic acids were immediately reduced with samarium diiodide in the presence of protic solvent under the basic medium at room temperature to the corresponding alcohols in good yields. The similar reaction of sodium benzoate in the absence of protic solvent afforded the reductive carbon-carbon coupling products.

Rapid development in application of lanthanides to organic synthesis has been recently achieved.[1)] In particular, the reactivity of samarium diiodide (SmI_2) toward the organic functionalities has attracted much attention from the standpoint of the reducing property and its great affinity for oxygen atom of carbonyl group.[1d)] However, reports of reduction of carboxylic acid using SmI_2 have apparently not been published previously and Kagan et al.[2)] reported that carboxylic acid and ester could not be reduced by SmI_2.

In general, carboxyl functionality is hardly reduced with the ordinary reducing agents except for diborane,[3)] lithium aluminum hydride,[4)] diisobutylaluminum hydride[5)] and sodium bis(2-methoxyethoxy)aluminum hydride.[6)] Moreover, these reducing agents can not be used in the presence of water. However, taking into account the great reducing property of SmI_2, the reduction of carboxyl functionality was expected to occur with SmI_2. In the present paper, we have found that SmI_2 can immediately reduce carboxylic acids in good yields when the reduction is carried out in basic media. The overall sequence is shown as follows:

$$\text{R-COOY} \xrightarrow{\text{SmI}_2\text{ in THF/R'OH/Base, RT}} \text{R-CH}_2\text{OH}$$

R: aryl, alkyl Y: H, Na Base: NaOH, $LiNH_2$, NH_3 or none
R': H, CH3

Our first trial was conducted with the reaction of benzoic acid (**1**) with SmI_2 in 10% NaOH/tetrahydrofuran (THF). A 10% NaOH (1 ml) solution of benzoic acid (**1**) (0.5 mmol) was added to a THF solution of SmI_2 (20 ml, 0.1 M, 2 mmol) and NaOH (4 mmol) at room temperature under argon. The typical blue color of SmI_2 was immediately decolored (within one minute). After the usual work-up, benzyl alcohol (**7**) was obtained in 91% yield. As shown in Table 1, carboxylic acids (**2-6**) were immediately reduced with SmI_2 under the similar conditions to the corresponding alcohols (**8-12**) in good yields. The similar reaction of cinnamic acid (**13**) using 8 equivalent moles of SmI_2 afforded 3-phenylpropanol (**14**) (39%) accompanied with 3-phenylpropionic acid (**15**).

Table 1. Reduction of Carboxylic Acids with SmI_2 in $THF/H_2O/NaOH$[a)] at Room Temperature[b)]

R-COOH[c)]	SmI_2[d)] mmol	Time s	Product	Yield[e)] %
C_6H_5COOH (**1**)	2	60	$C_6H_5CH_2OH$ (**7**)	91
$C_6H_{11}COOH$ (**2**)	2	58	$C_6H_{11}CH_2OH$ (**8**)	78
$CH_3(CH_2)_3CH(C_2H_5)COOH$ (**3**)	2	10	$CH_3(CH_2)_3CH(C_2H_5)CH_2OH$ (**9**)	94
$CH_3(CH_2)_4COOH$ (**4**)	2	271	$CH_3(CH_2)_4CH_2OH$ (**10**)	61
$CH_3(CH_2)_5COOH$ (**5**)	2	291	$CH_3(CH_2)_5CH_2OH$ (**11**)	57
$C_6H_5CH_2COOH$ (**6**)	2	82	$C_6H_5CH_2CH_2OH$ (**12**)	73
$C_6H_5CH=CHCOOH$ (**13**)[f)]	4	5	$C_6H_5CH_2CH_2CH_2OH$ (**14**)	39
			$C_6H_5CH_2CH_2COOH$ (**15**)	7

a) In these reactions, 2 mol eq of NaOH against SmI_2 were used. b) Reactions were carried out under argon. c) R-COOH (0.5 mmol) was dissolved in 10% NaOH of 1 ml. d) SmI_2 in THF (0.1 M). e) Isolated yield. f) Kagan et al. reported that reduction of acid **13** with SmI_2 in THF/MeOH (24 h) gave only acid **15** in 98% yields (Ref. 2).

In order to investigate the effect of the other bases and hydrogen source, our next trial was conducted with the similar reaction of benzoic acid **1** using the other bases in methanol/or in the absence of protic solvent. Firstly, as shown in Table 2, the reduction of **1** with SmI_2 did not proceed in the absence of base and protic solvent (Entries 1 and 2). Compared with the lower yields of product in the reaction using NH_3 (Entry 6), the results of reactions using $LiNH_2$ were almost similar to those of using NaOH (Entry 8). Reactions in methanol exhibited the longer reaction time and the lower yields (Entries 3 and 7) compared with the results in H_2O (Entry 5). On the other hand, in the absence of protic solvent, the similar reactions gave the lower yield of alcohol **7** and the longer reaction time was required (Entries 9 and 10). Furthermore, sodium benzoate (**16**) was similarly reduced with SmI_2 in the absence of base to benzyl alcohol **7** in an excellent yield (92%) (Entry 12).

In these reductions, it is presumed that the hydrogen source was in any event the hydrogen of H_2O, methanol or carboxylic acid since the similar reduction of sodium benzoate **16** using $LiNH_2$ in D_2O afforded $C_6H_5CD_2OH$ in 90% yields. Kagan et al. reported that the mechanism of the reaction with aprotic THF solution of SmI_2 involves an electron transfer from samarium to substrate and hydrogen abstraction from THF.[7)] Taking into account of this report, it is presumed that the hydrogen of THF was also used as the hydrogen source in the reductions of benzoic acid **1** in the absence of protic solvent (Entries 9 and 10).

Table 2. Reduction of Benzoic Acid (**1**) and Sodium Benzoate (**16**) with SmI_2[a]

Entry No.	C_6H_5COOY Y	mmol	SmI_2[b] mmol	Base	Base mmol	Protic Solvent	(ml)	Time	$C_6H_5CH_2OH$ Yield/%[c]
1	H	1	4	none		none		10 h[d]	0
2	H	0.25	1	none		MeOH	(10)	10 h	0.6
3	H	1	4	NaOH	2	MeOH	(10)	5 h	52
4	H	1	1	NaOH	1	H_2O	(2)	30 s	48
5	H	1	4	NaOH	8	H_2O	(2)	60 s	92
6	H	1	4	NH_3	10	H_2O	(2)	3 s	41
7	H	0.5	2	$LiNH_2$	2	MeOH	(2)	5 h	30
8	H	0.5	2	$LiNH_2$	4	H_2O	(1)	60 s	87
9	H	1	2	NaOH	2	none		4.3 h	42
10	H	0.5	2	$LiNH_2$	2	none		5 h	25
11	Na	1	2	none		H_2O	(2)	60 s	26
12	Na	1	4	none		H_2O	(2)	60 s	92
13	Na	1	2	NaOH	2	H_2O	(2)	60 s	72
14	Na	1	4	NaOH	5	H_2O	(2.5)	60 s	91

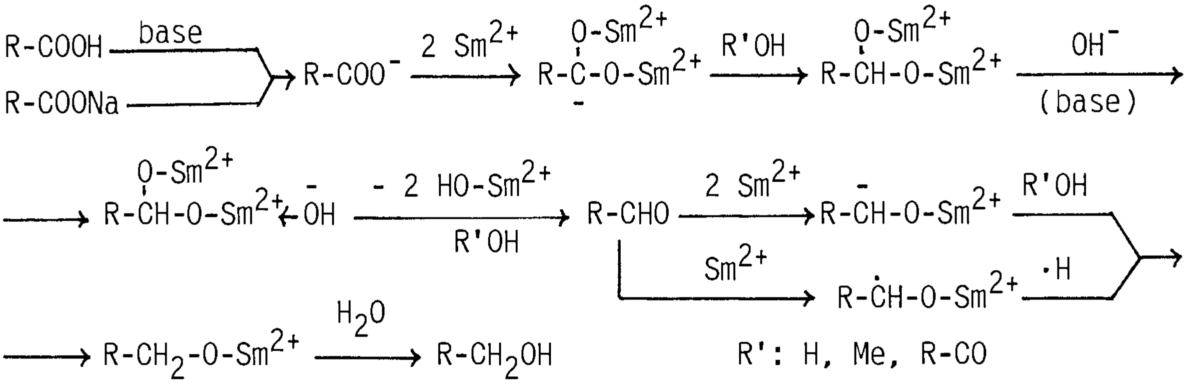
a) Reactions were carried out at room temperature under argon. b) SmI_2 in THF (0.1M). c) Isolated yields. d) Interrupted reaction time.

On the other hand, in the reaction of sodium benzoate **16** with SmI_2 in the absence of protic solvent (in THF), the reductive carbon-carbon coupling reaction proceeded to afford benzylphenylcarbinol (**17**), benzoin (**18**) and benzil (**19**) as the coupling products accompanied with benzyl alcohol **7**.

$$\underset{\mathbf{16}\quad 1\ \mathrm{mmol}}{C_6H_5COONa} \xrightarrow[\text{THF, NaOH, 7 h}]{SmI_2(1\ \mathrm{mmol})} \underset{\mathbf{17}\quad 22\%}{C_6H_5CH_2(C_6H_5)CHOH} + \underset{\mathbf{18}\quad \text{trace}}{C_6H_5CH(OH)COC_6H_5}$$

$$+ \underset{\mathbf{19}\quad \text{trace}}{C_6H_5COCOC_6H_5} + \underset{\mathbf{7}\quad 9\%}{C_6H_5CH_2OH}$$

As mentioned above, the striking characteristic of these reductions is the extremely short reaction time at room temperature which is based on the highly promoted electron transfer from SmI_2 by coexisting sodium hydroxide or the other bases. Accordingly, it is assumed that the reductant for these reductions may also be R_1-Sm-R_2 (R_1, R_2: I, OH or OCH_3) in addition to SmI_2. Though the actual reductant and the detailed mechanism of these reductions have remained obscure at the present stage, a possible mechanism for the present reduction is proposed in Scheme 1, which may explain the experimental results.



Scheme 1.

It is noteworthy that these reductions can be rapidly performed under mild conditions, so the SmI_2-base system provides a useful route for the direct reduction of carboxylic acids in synthetic chemistry.

References

1) a) H. B. Kagan and J. L. Namy, Tetrahedron, **24**, 6573 (1986) and references therein; b) T. Imamoto, Yuki Gosei Kagaku Kyokai Shi, **46**, 540 (1988); c) T. Imamoto, N. Takiyam, K. Nakamura, T. Hatajima, and Y. Kamiya, J. Am. Chem. Soc., **111**, 4392 (1989); d) J. Inanaga, Yuki Gosei Kagaku Kyokai Shi, **47**, 200 (1989) and references therein; e) M. Murakami, T. Kawano, and Y. Ito, J. Am. Chem. Soc., **112**, 2437 (1990).

2) P. Girard, J. L. Namy, and H. B. Kagan, J. Am. Chem. Soc., **102**, 2693 (1980).

3) H. C. Brown and B. C. Subba Rao, J. Chem. Soc., **82**, 681 (1960); H. C. Brown and W. Korytnyk, ibid., **82**, 3866 (1960); S. G. Batrakov and L. D. Bergelson, Izv. Akad. Nauk SSSR Ser. Khim., **1965**, 369; H. C. Brown, P. Heim, and N. M. Yoon, J. Am. Chem. Soc., **92**, 1637 (1970); N. M. Yoon, C. S. Pak, H. C. Brown, S. Krishnamurthy, and T. P. Stocky, J. Org. Chem., **38**, 2786 (1973).

4) H. C. Brown, P. M. Weissman, and N. M. Yoon, J. Am. Chem. Soc., **88**, 1458 (1966); M. Braid, H. Iserson, and F. E. Lawlor, ibid., **76**, 4027 (1954).

5) A. G. Miller, J. N. Biss, and L. H. Schwartzman, J. Org. Chem., **24**, 627 (1959).

6) V. Bazant, M. Čapka, M. Cerný, V. Chvalovský, K. Kochloefl, M. Kraus, and J. Målek, Tetrahedron Lett., **29**, 3303 (1968); M. Černý, J. Målek, M. Čapka, and V. Chvalovský, Collect. Czeck. Chem. Commun., **34**, 1025 (1969).

7) H. B. Kagan, J. L. Namy, and P. Girard, Tetrahedron, **34**, 175 (1981).

(Received February 27, 1991)